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Liu

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[45] **Date of Patent: Oct. 10, 2000**

[54] **ACCESS AND SETUP PROCESS FOR END-TO-END DATA AND ANALOG VOICE CONNECTIONS**

[75] Inventor: **Ming-Kang Liu**, Cupertino, Calif.

[73] Assignee: **Integrated Telecom Express**, Santa Clara, Calif.

[21] Appl. No.: **08/934,839**

[22] Filed: **Sep. 22, 1997**

[51] **Int. Cl.**[7] **H04J 3/22**

[52] **U.S. Cl.** **370/230**; 370/465

[58] **Field of Search** 370/230, 232–235, 370/465, 468, 410, 545

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Primary Examiner—Chi H. Pham
Assistant Examiner—Maikhana Tran
Attorney, Agent, or Firm—Law +

[57] **ABSTRACT**

A signaling protocol process is described for setting up and controlling end to end data link connections. An optimal data path can be selected and configured by a digital subscriber loop (DSL) user based on particular bandwidth requirements, data rate cost constraints, and/or data delay requirements. The data path can be set up to include one or more data routes, including through a regular digital public switching telephone network (PSTN), various kinds of wide area networks (WANs), and virtual permanent circuit links via digital cross-connects (DCS).

20 Claims, 7 Drawing Sheets

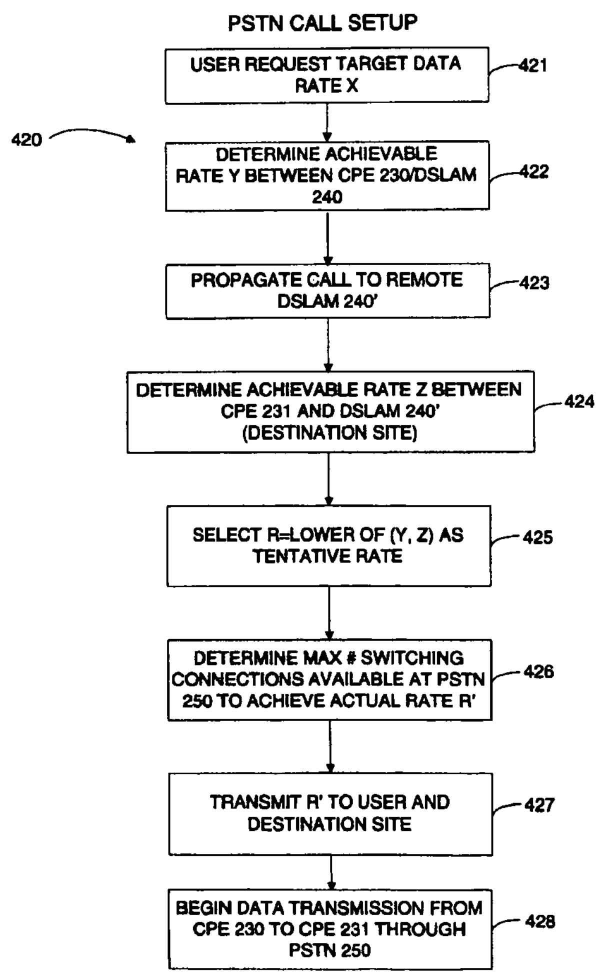


FIGURE 1A
(Prior Art)

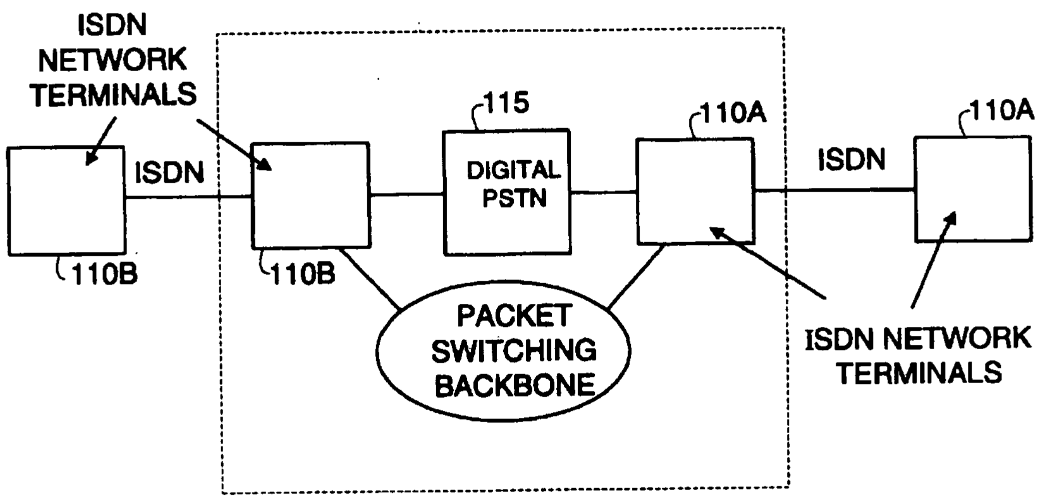


FIGURE 1B
(Prior Art)

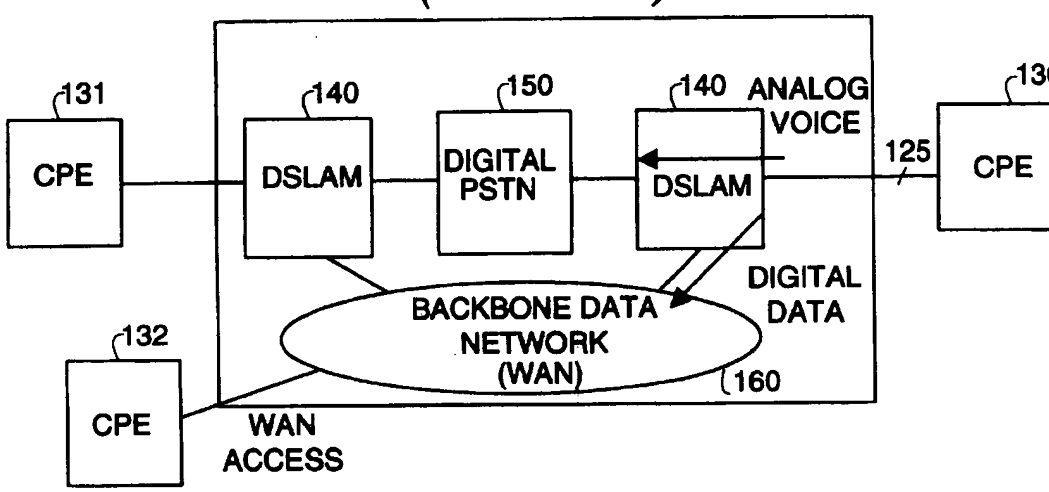


FIGURE 2

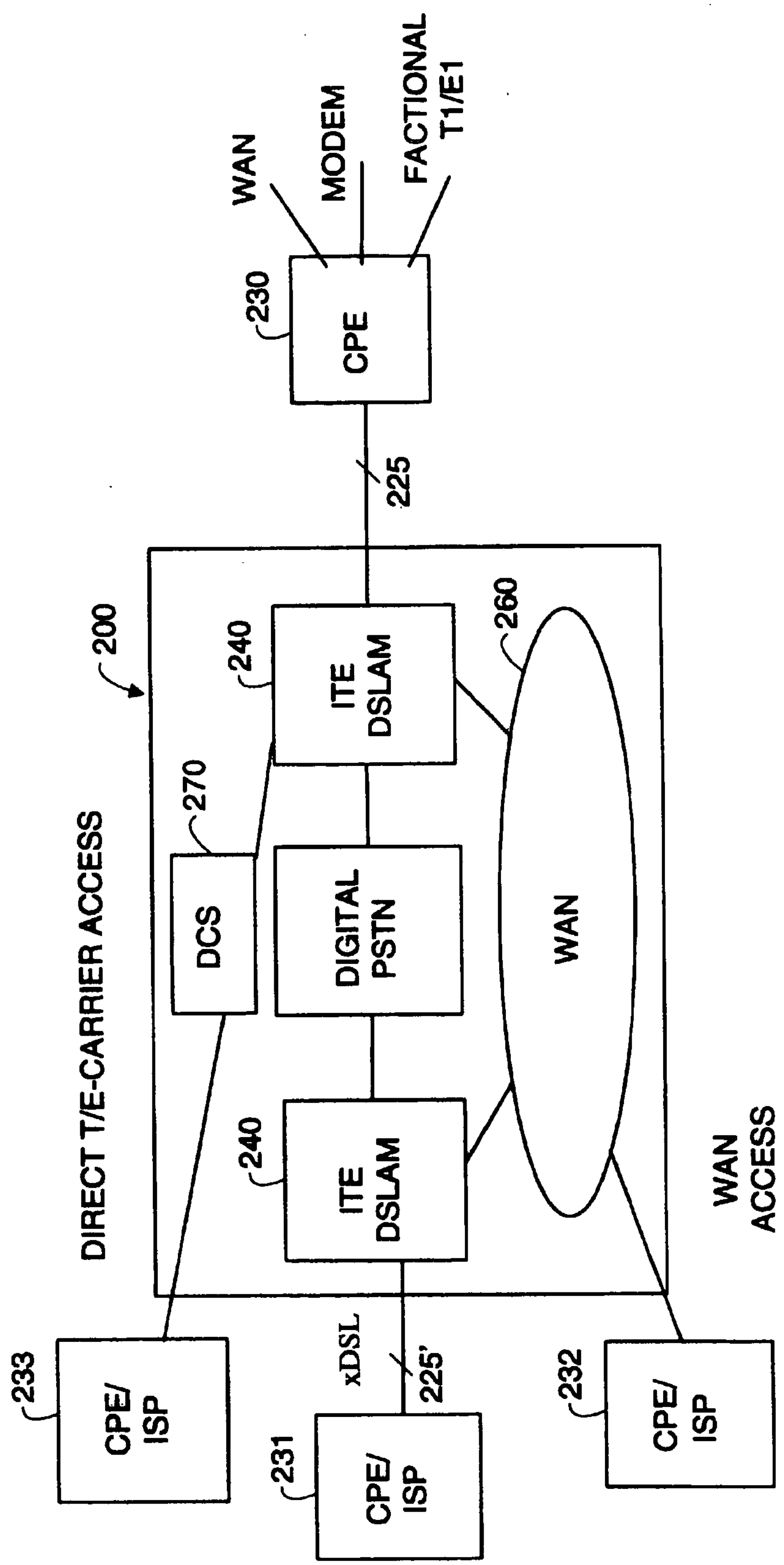
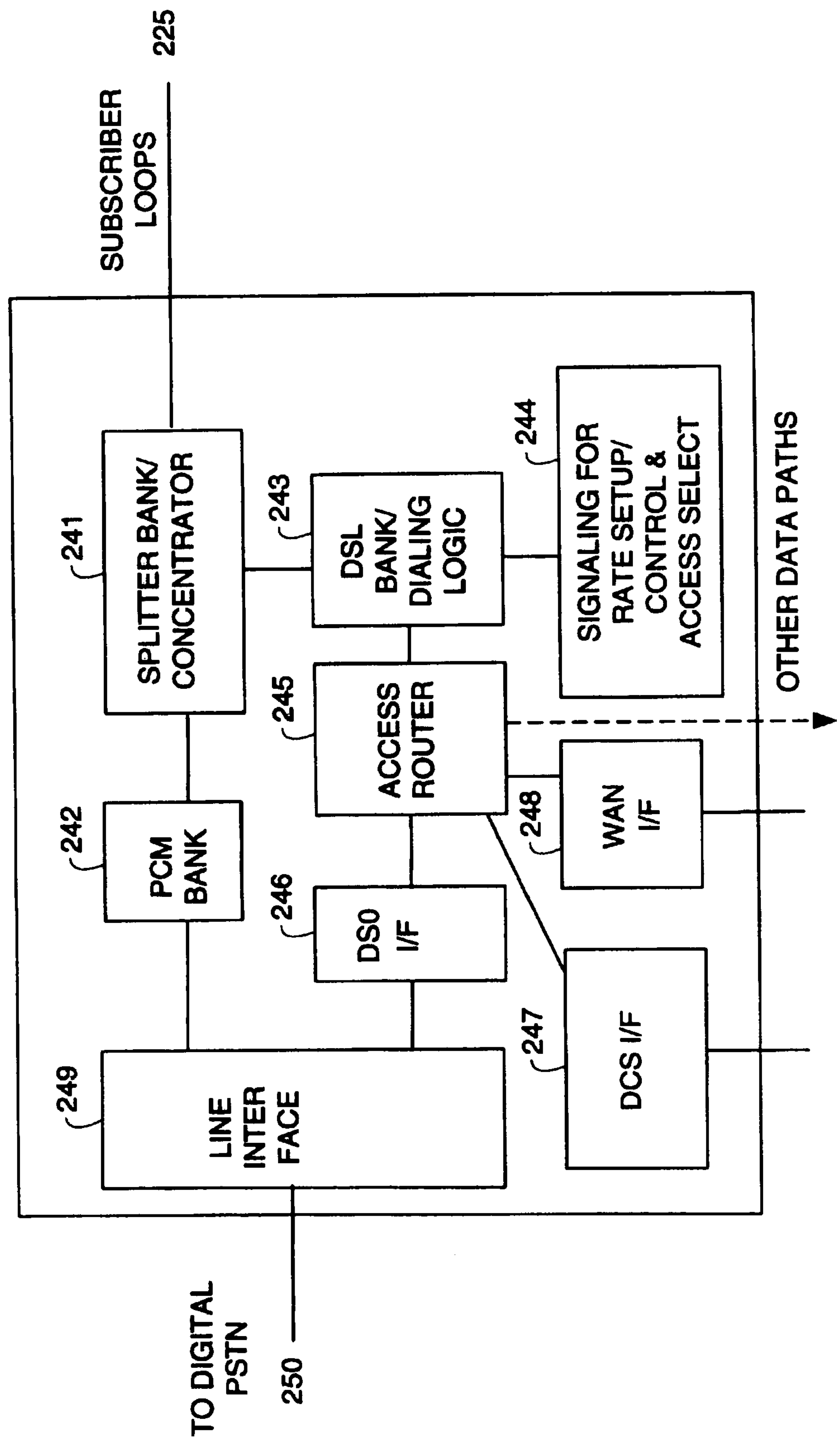

WAN
MODEM
FACTIONAL
T1/E1
230
CPE
225
200
DIRECT T/E-CARRIER ACCESS
240
ITE
DSLAM
260
270
DCS
DIGITAL
PSTN
WAN
240
ITE
DSLAM
WAN
ACCESS
233
CPE/
ISP
xDSL
225'
231
CPE/
ISP
232
CPE/
ISP

FIGURE 3



225
SUBSCRIBER LOOPS
241
SPLITTER BANK/ CONCENTRATOR
242
PCM BANK
243
DSL BANK/ DIALING LOGIC
244
SIGNALING FOR RATE SETUP/ CONTROL & ACCESS SELECT
245
ACCESS ROUTER
246
DS0 I/F
247
DCS I/F
248
WAN I/F
249
LINE INTER FACE
OTHER DATA PATHS
TO DIGITAL PSTN
250

FIGURE 4A

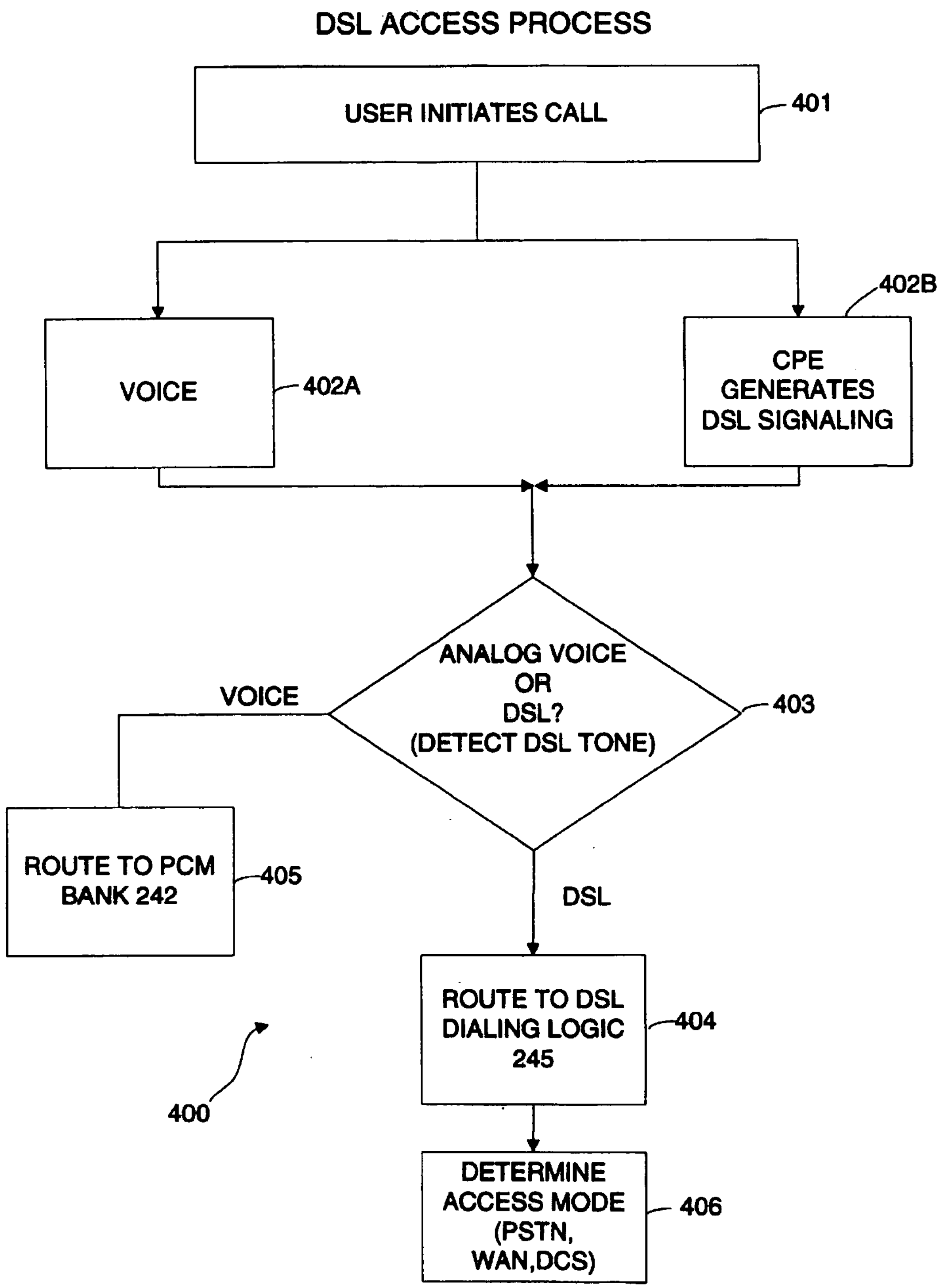

DSL ACCESS PROCESS
USER INITIATES CALL
401
VOICE
402A
CPE GENERATES DSL SIGNALING
402B
ANALOG VOICE OR DSL? (DETECT DSL TONE)
403
VOICE
DSL
ROUTE TO PCM BANK 242
405
ROUTE TO DSL DIALING LOGIC 245
404
DETERMINE ACCESS MODE (PSTN, WAN,DCS)
406
400

FIGURE 4B

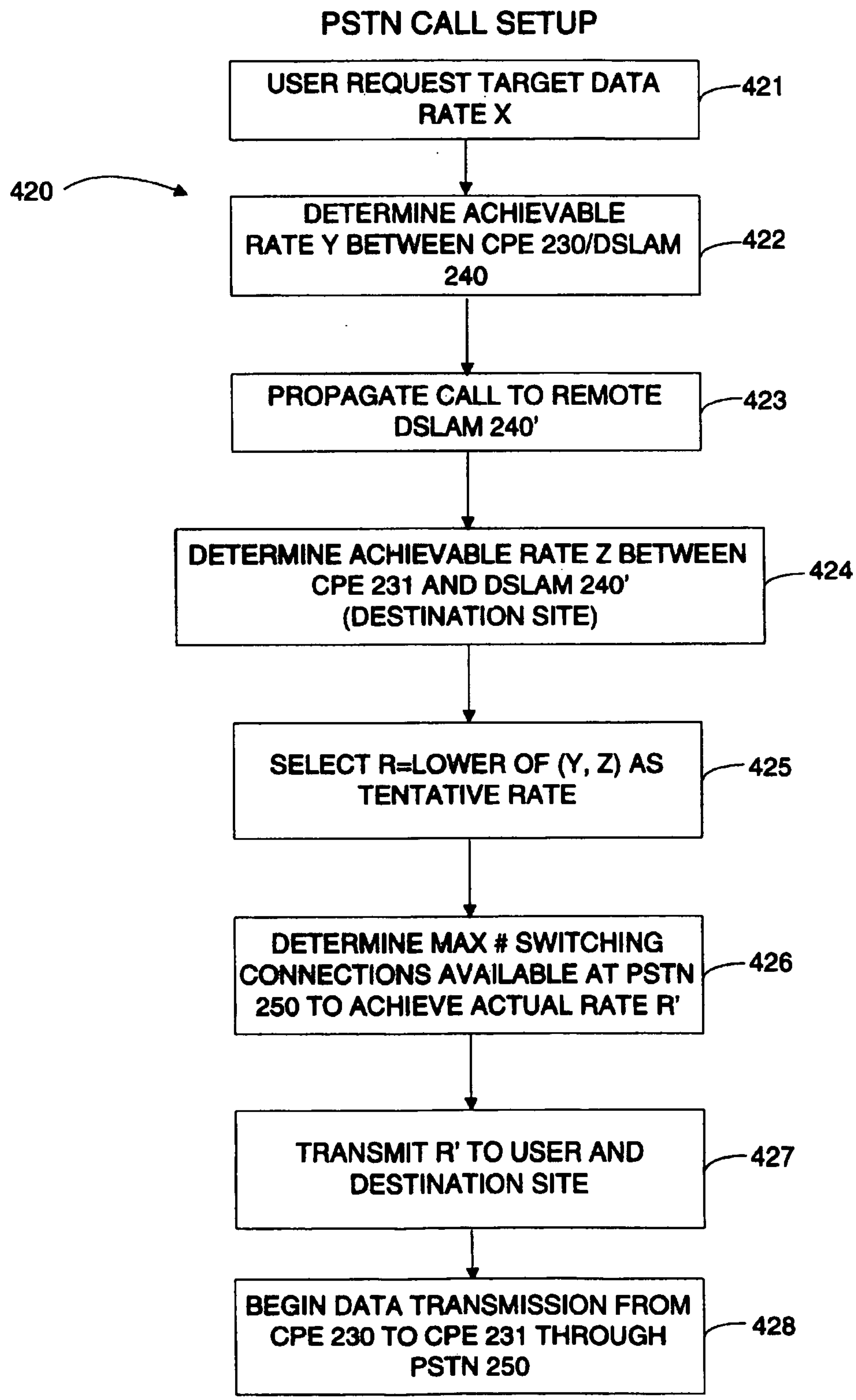

PSTN CALL SETUP
420
USER REQUEST TARGET DATA RATE X
421
DETERMINE ACHIEVABLE RATE Y BETWEEN CPE 230/DSLAM 240
422
PROPAGATE CALL TO REMOTE DSLAM 240'
423
DETERMINE ACHIEVABLE RATE Z BETWEEN CPE 231 AND DSLAM 240' (DESTINATION SITE)
424
SELECT R=LOWER OF (Y, Z) AS TENTATIVE RATE
425
DETERMINE MAX # SWITCHING CONNECTIONS AVAILABLE AT PSTN 250 TO ACHIEVE ACTUAL RATE R'
426
TRANSMIT R' TO USER AND DESTINATION SITE
427
BEGIN DATA TRANSMISSION FROM CPE 230 TO CPE 231 THROUGH PSTN 250
428

FIGURE 4C

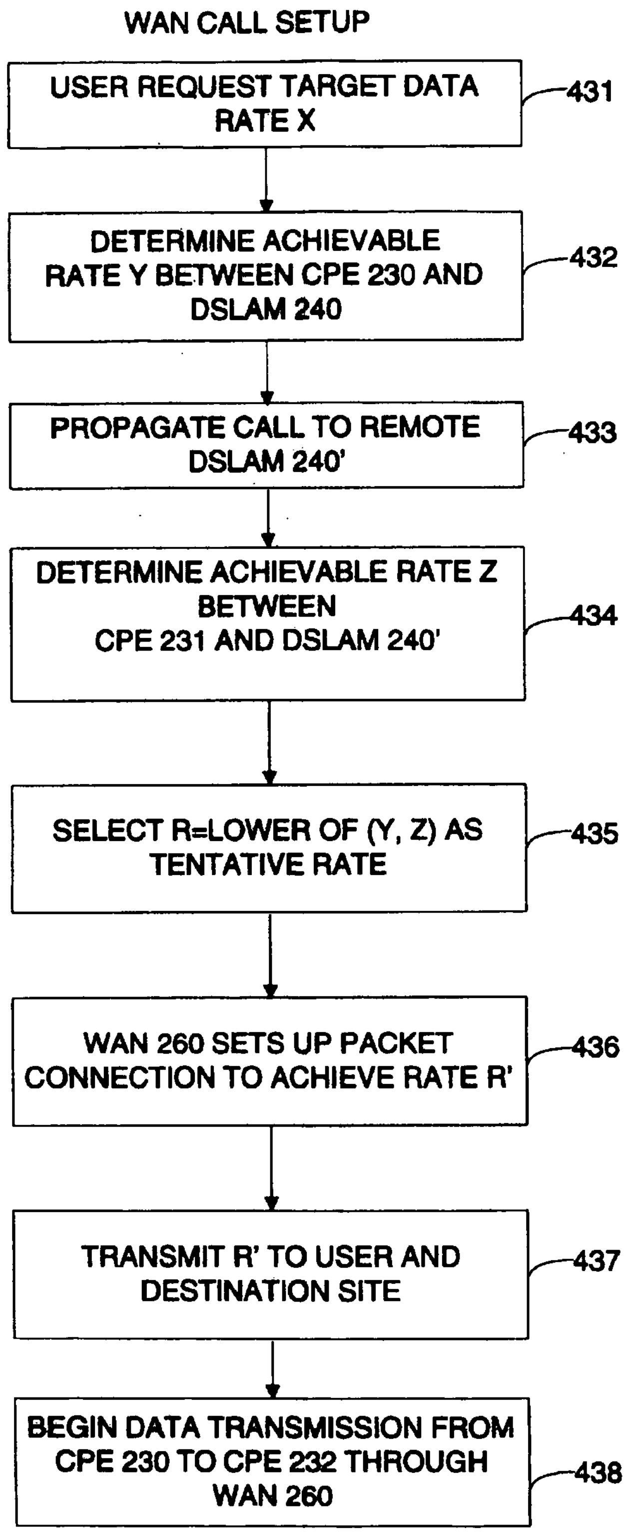
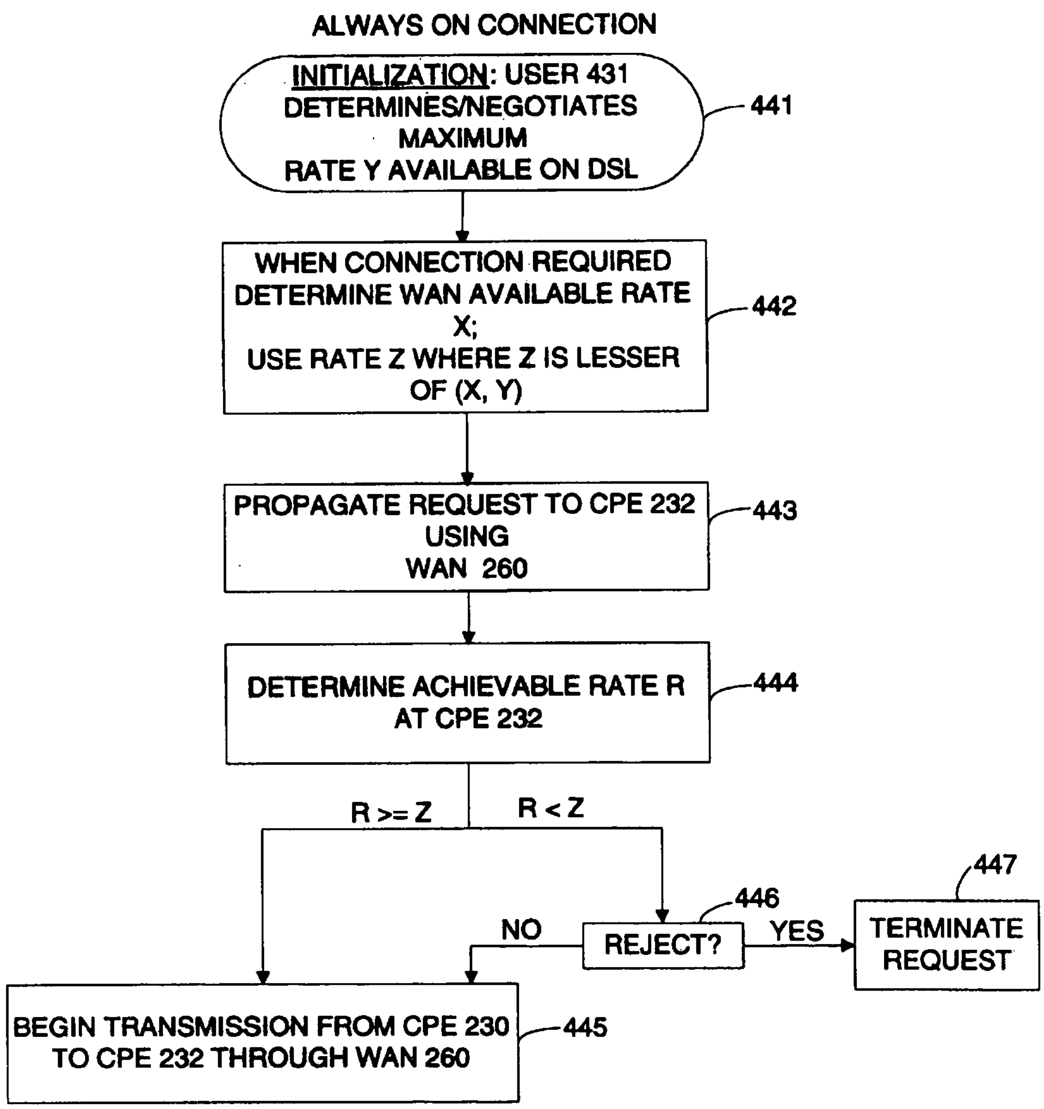

WAN CALL SETUP
USER REQUEST TARGET DATA RATE X
431
DETERMINE ACHIEVABLE RATE Y BETWEEN CPE 230 AND DSLAM 240
432
PROPAGATE CALL TO REMOTE DSLAM 240'
433
DETERMINE ACHIEVABLE RATE Z BETWEEN CPE 231 AND DSLAM 240'
434
SELECT R=LOWER OF (Y, Z) AS TENTATIVE RATE
435
WAN 260 SETS UP PACKET CONNECTION TO ACHIEVE RATE R'
436
TRANSMIT R' TO USER AND DESTINATION SITE
437
BEGIN DATA TRANSMISSION FROM CPE 230 TO CPE 232 THROUGH WAN 260
438

FIGURE 4D


ALWAYS ON CONNECTION
INITIALIZATION: USER 431 DETERMINES/NEGOTIATES MAXIMUM RATE Y AVAILABLE ON DSL
441
WHEN CONNECTION REQUIRED DETERMINE WAN AVAILABLE RATE X; USE RATE Z WHERE Z IS LESSER OF (X, Y)
442
PROPAGATE REQUEST TO CPE 232 USING WAN 260
443
DETERMINE ACHIEVABLE RATE R AT CPE 232
444
R >= Z
R < Z
447
446
NO
REJECT?
YES
TERMINATE REQUEST
BEGIN TRANSMISSION FROM CPE 230 TO CPE 232 THROUGH WAN 260
445

ACCESS AND SETUP PROCESS FOR END-TO-END DATA AND ANALOG VOICE CONNECTIONS

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is related to the following additional applications filed concurrently herewith:

Attorney Docket No. ITE 97-013 entitled "Configurable Digital Subscriber Loop Access and End-to-End Data and Analog Voice Connection System."

Attorney Docket No. ITE 97-014 entitled "Digital Subscriber Loop Access Circuit for Digital Switch and Packet Network Interconnections."

FIELD OF THE INVENTION

The invention relates generally to an access, setup and configuration process for setting up and dynamically configuring an optimal data path routing for an end-to-end data link connection. In particular, the present invention permits a digital subscriber loop (DSL) user, based on total bandwidth requirements, cost requirements, and/or data delay requirements, to optimally configure an end-to-end data path using one or more data routes, including through a regular digital public switching telephone network (PSTN), various kinds of wide area network (WAN), and virtual permanent circuit links via digital cross-connects (DCS).

BACKGROUND OF THE INVENTION

To provide high bit rate transmission over existing telephone subscriber loops, various modem technologies have been proposed. One of the promising solutions is the Asymmetric Digital Subscriber Loop (ADSL) technology that can provide up to 6.144 Mb/s transmission from the central office to a subscriber (downstream) and up to 640 kb/s transmission from the subscriber to the central office (upstream).

As the DSL technology rapidly advances, there is a strong need for the carrier (i.e. phone companies) to provide cost-effective, end-to-end, and high-speed interconnection. However, as explained below, there are many complex issues arising at both the upstream and downstream sites that make it difficult to develop cost-effective and easy-to-install and use solutions.

First, because of the earlier PCM (pulse code modulation) design where analog voice is digitized at a rate of 64 kb/s, the digital telephone switches installed in the Public Switched Telephone Network (PSTN) currently provide only 64 kb/s end-to-end connections. For example, ISDN is a DSL technology that can provide end-to-end circuit switching at a rate of multiple 64 kb/s. Each 64 kb/s link in ISDN is called a B channel and users who want a circuit connection at a rate higher than 64 kb/s needs to use multiple 64 kb/s links at the same time. In this case, all source signals are digital (voice will be sampled to 64 kb/s at the user site) and transmitted over individual B channels. They can be switched by either a digital PSTN **115** or packet switching backbone network **120** as shown in FIG. 1A. In this case, ISDN has the following limitations: (1) The transmission rate over the ISDN line (i.e., from IDSN Network Terminal **110A** to **110B**) is fixed and cannot be expanded (e.g. basic rate ISDN is 128 kb/s and primary rate ISDN is 1536 kb/s). For high performance services such as video conferencing or graphic file transfers, this data rate is not useful and/or it takes too long in time to transfer. (2) Voice traffic is carried

via 64 kb/s PCM or one B-channel. Compared to a typical basic rate access of 2 B-channels, voice connection consumes a large portion of the total bit rate. (3) The protocol for connection over packet-switching backbone network **120** is standardized and requires the other end to follow the same protocol. For ADSL access where transmission rates are in the order of Mb/s, use of a large number of B channels (i.e., multiple ISDN connections) is practically undesirable due to the cost of multiple fixed switched connections. Furthermore, even though the ADSL transmission rate is high, it may not require a constant transmission rate (as is provided by a typical ISDN direct switched connection) all the time for many practical applications such as Internet access.

To overcome the above problems, packet switching (in contrast to circuit switching) based solutions for xDSL such as ATM and Frame Relay have been proposed. The term "xDSL" generally refers to a superset of various digital subscriber loop technologies, including ADSL, HDSL, etc. In particular, WANs (as used herein, "WAN" refers to any packet-switching based network such as Frame Relay, ATM, or SMDS (Switched Megabit Data Service)) can provide packet-switched based connections at variable rates and have been proposed to support xDSL. An example of a WAN arrangement **180** is shown in FIG. 1B. In this arrangement, connections at a rate other than multiple 64 kb/s between two CPEs **130** and **132** can be established through WAN backbone data network **160** at a lower cost due to bandwidth sharing. Because they are very suitable for data transfer, these types of high-speed backbones have been widely used in LAN interconnections as well. However, they do not guarantee fixed transfer delay. Therefore, they are not suitable for time-sensitive services such as video conferencing. In addition, they require non-trivial network access setups. As a result, they are difficult for ordinary users to install and maintain. To terminate an xDSL line **125** and connect it to a WAN **160**, a piece of equipment called DSLAM (DSL Access and Multiplexer) **140** is used. As shown in FIG. 1B, a DSLAM splits a subscriber loop **125** to a PSTN **150** for analog voice signals and the WAN **160** for data transmission. As shown, however, the above DSLAM based architecture has the following known limitations. (1) Data transmission always goes through the same backbone data network **160**. It is desirable to be able to use the PSTN **150** for switching time-sensitive services. (2) As a result, this type of arrangement does not support end-to-end circuit switching other than Plain Old Telephone Services (POTs), and data communications using voice-band modems. This prohibits the use of the current suggested DSL "modem model" in which end-users at CPE **130** can "dial-up" any remote site **131**, **132** with a compatible modem user model. Instead, users need to set up all the necessary network addresses for both the host and intermediate nodes. This can be troublesome for most end users and especially a problem when the network needs to be upgraded (i.e. the network is no longer transparent to users). (3) It does not have the ability to split the data signals carried by the xDSL **125** into two paths: one through the PSTN **150** and one through the WAN **160**. The access to the WAN **160** needs to support the maximum xDSL rate. If not, the high-speed transmission over the DSL becomes wasted. On the other hand, the access cost to the WAN for this type of data rate can be expensive. This poses a challenging problem for the carriers to price xDSL access.

Furthermore, the cost of DSL codecs and access equipment are currently much higher than that of voice-band modems. Therefore, even though the speed is much higher than the current 33.6 kb/s or 56 kb/s, most end-users will not

afford to upgrade this new technology. A lower cost alternative is thus desirable that users can spend less initially for a lower speed and upgrade it at a later time as demands increase.

In addition to the equipment cost, xDSL users will have to spend much more for the access to a high-speed backbone network. In contrast to the current case where modem users do not need to pay any additional cost, this poses another barrier for adoption of xDSL technology. Users who subscribe to Frame Relay or T1 access typically need to spend $1,000 or even more every month, a figure which is beyond the means of the majority of potential users of such technology.

A critical need, therefore, exists for a solution that minimizes accesses charges while at the same time allowing carriers to enjoy a reasonable commercial return on their investments in higher end equipment to provide ADSL, services. To address this need, a forward compatible and expandable xDSL modem or so-called "SAM" (scaleable ADSL modem) has been proposed as a low cost solution at the end-user side in pending U.S. application Ser. No. 08/884,995 filed Jun. 30, 1997 entitled "Rate Adaptable Modem With Forward Compatible and Expandable Functionality and Method of Operation," also assigned to the present assignee. The invention of that SAM disclosure makes it possible for downstream users to avoid the cost associated with an expensive ADSL modem when they do not need full ADSL transmission rate. In an analogous fashion, it would be attractive and advantageous to extend some of the principles of the above SAM disclosures to the upstream sites. In other words, the central office should be able to effectuate an end-to-end architecture that: (i) permits users to only pay carriers a fee necessary to procure a particular desired target data rate (which may be only a fractional portion of a full ADSL data link); (ii) allows users to establish a particular kind of data link (real-time or delayed); (iii) allows users to accept the lowest cost per unit of bandwidth; or (iv) facilitates a data route which is more suited to particular user's connection model.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide an end-to-end architecture and system that permits users to flexibly, transparently, and dynamically configure high-speed connections based on criteria such as their particular data rate needs, associated costs of using various data paths, bandwidth availability, access costs, and suitability to the user's connection model.

Another object of the present invention therefore is to provide an access and multiplexing circuit for use in a central office that permits a user to configure and control an end-to-end connection, including a target data rate, via either the current digital PSTN, a packet-based WAN interconnection, or a digital cross-connect.

A further object of the present invention is therefore to provide a flexible and efficient access and setup process for permitting DSL users to configure and control an end-to-end connection, including a target data rate and connection path via either the digital PSTN, a packet-based WAN interconnection, or a digital cross-connect.

Yet a further object of the present invention is to provide an end-to-end connection that is still nevertheless backwards compatible with existing subscriber loop access protocols and is also forwards compatible with proposed partial DSL bandwidth CPE/ISPs at downstream sites;

Yet another objective is to provide a new DSLAM architecture that allows users to incrementally pay for the access fee according to their speed and service requirements.

The objects of the present invention are effectuated by providing a system that establishes an end-to-end data path connection between a data link requesting site and a destination site based on a data route request provided by a user at the origination site. At the central office site, an interface circuit receives voice, data, and the data route request signals from a digital subscriber loop (DSL) coupled to the user's device at the origination site. A data routing control circuit then evaluates and sets up a data route between the origination site and the destination site using the most optimal data path matching the user's request. This data path can include any one or more of the following: (i) a circuit switched PSTN; and/or (ii) a wide area network (WAN); and/or (iii) a digital cross-connect. Other data paths compatible with a PSTN and WAN are also possible. After the link is established, an access router is then used for routing the user's data through the selected data path.

Each of the various data paths has its transmission characteristics, including among other things, a maximum data rate, transfer delay, cost per unit bandwidth, connection model, etc. In the data route request, the user can specify any requirements for these and similar parameters, and the routing control circuit determines which of the available paths most conforms to such request, thereby effectuating a data path most suited for the user's needs. For example, if a very high speed link is required (in excess of 128 Kbs), a WAN may be selected, so long as the other user defined constraints are met by such data path. This type of data path optionally transfers data using any or all of the following: frame relay, and asynchronous transfer mode (ATM). In determining the data transfer rate of any path, the system also takes into consideration the capabilities of any digital subscriber loops coupled to the various communicating sites, as well as the data processing capabilities available at these sites. For time delay sensitive applications, such as video teleconferencing, a switched network, such as the PSTN may be used instead. This can be achieved by setting up one or more dedicated 64 Kb/s links. Similarly, if low cost is the most important specified criterion in the request, the system can also dynamically determine and select the data path having the lowest cost per unit of bandwidth at the time of the request.

In a preferred embodiment of this system, the interface circuit also separates the data into voice signals and DSL signals. A pulse code modulation circuit then converts the voice signals into digital voice signals for routing through the switched network. The access router is coupled to all the available data paths, including (i) a circuit switched PSTN; (ii) a wide area network interface circuit; and (iii) a digital cross-connect interface circuit.

An access and setup process is also described for accessing and configuring a variety of optimal end-to-end data path modes, including end-to-end switching through a PSTN, end-to-end switching through a WAN, and through an "always-on" type connection. First, a user initiates a connection and transmits an access request to a local central office. The access request can include information concerning a requested data route, target data rate, user connection model, desired cost for the transmission, etc. At the central office, determination is made concerning whether the access request is related to voice signal transmission or a data signal transmission. Based on the parameters of the request, a data route is configured to accomplish the data transfer. The access request can specify a particular data path, or alternatively, can specify that a DSLAM circuit in the central office should select a particular access mode (i.e., the most optimal data path matching the access request requirements) for transmitting data.

In an embodiment where an end-to-end connection is requested through the PSTN, a data path at a data rate of some multiple of 64 kb/s can be set up for applications, which, for example, require realtime performance. After requesting a data path at a particular target rate requested by the user, an evaluation is made of the line qualities between the CO and the communicating sites to ascertain the target rate. The PSTN then allocates and sets up multiple available 64 kb/s connections to try and satisfy the target rate transmission. Thereafter communications can proceed between the two sites at such rate.

In another embodiment where an end-to-end connection is implemented through a WAN, a data path at a certain target data rate can be set up for applications which require a higher data rate, or as is often the case, a lower cost per unit of bandwidth. As above, after requesting a data path at a particular target rate, an evaluation is made of the line qualities between the CO and the communicating sites to ascertain the target transmission rate. The WAN then allocates and sets up sufficient bandwidths to try and satisfy the maximum target transmission data rate. Thereafter communications can proceed between the two sites at such rate.

In applications where a permanent, "always on" DST, connection exists to the central office, a slightly different process can be used. First, to start the connection (turn it on initially) a negotiations procedure is effectuated which determines the highest achievable rate X available through the DSL connection. A WAN having a particular available rate Y is used for effectuating the end-to-end packet-switching connection (i.e., by Frame Relay or ATM) at a rate which is the lesser of X and Y. In the case where Y is smaller than X, a reduced rate Y is proposed to the origination site, which can accept such proposal, or reject the request. A similar negotiation procedure is effectuated at the destination site to determine the maximum rate achievable by that site's DSL. If both sites confirm the request, an end-to-end connection is established for data transmission.

The architecture of the present system combines current DSLAM functions (ATM and/or Frame Relay accesses) with user-configurable end-to-end circuit switching capability. That is, users can decide the rate and ask for connection via either the current digital PSTN packet-based WAN interconnection, or virtual permanent DCS connections. The choice they make can be based on their particular service requirements and the cost they are willing to pay for such service on a call by call basis. The present invention can be loaded directly on top of preexisting switching network infrastructures, and furthermore, permits carriers to more easily allocate the cost of routing data in a manner proportionate to the service requested by a user. For example, an appropriate cost allocation can now be made for delay-sensitive services that require direct switched connections, as opposed to non-delay sensitive services, such as Internet access, which only require packet switching (or the like) connections. Therefore, it provides a smooth migration for all current modem, ISDN, and LAN users. Furthermore, when used in combination with a SAM type transceiver at the end-user side, it provides a very low-cost, end-to-end solution for users who need only connections at a data rate around several hundred kb/s but want to reserve the option of upgrading to a higher performance standard at a later time.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a block diagram depiction of a prior art ISDN end-to-end switching network;

FIG. 1B is a block diagram depiction of a prior art based end-to-end switching network;

FIG. 2 is an electrical block diagram depiction of a switching network constructed in accordance with the teachings of the present DSLAM invention;

FIG. 3 is an electrical block diagram of a DSL Access and Multiplex (DSLAM) circuit implemented using the teachings of the present invention;

FIG. 4A is a flow chart illustrating an access setup process for setting up an end-to-end connection through either a PSTN, DCS or WAN in accordance with the present disclosure;

FIG. 4B is a flow chart illustrating a call setup process for setting up an end-to-end connection through the PSTN in accordance with the present disclosure; and

FIG. 4C is a flow chart illustrating a call setup process for setting up an end-to-end connection through a packet switching network in accordance with the present disclosure;

FIG. 4D is a flow chart illustrating a call setup process for setting up an end-to-end connection through an "always on" data channel in accordance with the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

Architecture of the Present Invention

FIG. 2 illustrates the new overall end-to-end DSL access switching network **200** proposed by the applicants. The primary highlight of the present invention is an improved DSLAM **240**, which provides connection of a DSL line **225** to all data paths within the switching network **200**, including PSTN **250**, WAN **260**, and various digital cross-connects (DCS) **270**. Except where noted, DSL, line **225**, PSTN **250**, WAN **260**, and CPE/ISPs **230**, **231**, **232**, **233** etc., correspond generally to their well-known counterparts already discussed in connection with FIGS. **1A** and **1B**.

As described herein, the circuitry of DSLAM **240** effectuates the following operational characteristics:

(1) A high speed DSL line **225** can be connected to PSTN **250**, WAN **260**, and DCS **270** at the same time by splitting its data stream according to user requirements and available connections;

(2) An end-to-end circuit-switching link between downstream CPE **230** and remote CPEs **231**, **232**, **233** can be established by connecting multiple 64 kb/s lines through PSTN **250**. The total speed can be increased as the DSL line speed increases, and as the user at CPE **230** desires to augment data rate capacity. This capability provides satisfactory connections for time-sensitive services such as video conferencing.

(3) When the PSTN data route is used (i.e., using a direct switched connection through PSTN **250**), users can operate the DSL line **225** as is done with current conventional modem usages. The primary difference using the present invention is a higher speed line. This minimizes the effort for users to upgrade to xDSL by avoiding unnecessary network setups.

(4) When the WAN route is used (i.e., using a packet switched connection through WAN **260**), users can operate the DSL line either as the current modem use with new invented DSLAM features to be described shortly, or as a virtual connection through standard packet switching setup protocols.

(5) Multiple access protocols are supported over the same DSLAM interface **240**, which provides gateway func-

tions to route DSL traffic to either PSTN **250** which is circuit-switched or WAN **260** which is based on Frame Relay, ATM, etc.

(6) Depending on the cost of access through the PSTN **250** and WAN **260**, users can select the most economic connection at the given data rate and the service requirement. For example, when users need only 128 kb/s transmission, it would be more cost-effective to use the PSTN **250** than WAN **260**. On the other hand, for very high-speed data transmission, it would be more cost effective to use the WAN **260** for its bandwidth sharing nature.

(7) When the present invention is further integrated with a SAM type downstream transceiver at the CPE, users can start with a lower data rate (several hundred bits/sec) access and then increase it as needed.

A detailed block diagram of the DSLAM **240** architecture is shown in FIG. **3**. Splitter Bank/Concentrator circuit **241** interfaces to a number of subscriber loops **225** which concentrates and then splits the physical signals on such loops to (1) a PCM bank **242** for voice calls or analog modem connections and (2) to a DSL Bank/Dialing Logic block **243** for DSL access. By concentrating the subscriber loops **225**, the number of PCM and DSL codecs in stages **242, 243** can be reduced. PCM Bank **242** in the DSLAM is unique to the present invention, and is not used in any prior art DSLAM circuits known to the applicants. Instead of forwarding analog voice signals directly to phone switch **250**, voice signals are first converted to PCM. This allows either T or E-carrier interface to switch **250**, which increases the cost effectiveness and permits a standard interface to a digital switch.

DSL Bank/Dialing Logic circuit **243**, depending on the DSL codec being used, converts DSL signals to digital data signals that can be routed to the various data paths described below. This circuit also provides the necessary processing during call setup and tear down (both discussed in more detail below). Signaling for Rate Setup/Control and Access Select circuit **244**, based on the signaling exchanged with remote site **230**, controls Access Router **245** and determine how the user data stream will be routed. For example, it negotiates the final data rate with the remote user, and decides the connection method (dialing up the destination as current modem use via either the PSTN **250** or WAN **260**, or setting up a virtual circuit via the WAN). Access Router stage **245** routes the data streams to three main possible routes: DS0 interface **246**, DCS interface **247**, and WAN interface **248**. In this manner, a single DSL connection can be connected to multiple routes at the same time. DS0 Interface circuit **246** converts DSL bit streams into multiple B-channels (called DS0 in digital telephone networks) and multiplexes them to either T or E-carrier signals, which are then connected to the PSTN via Line Interface **249**. WAN Interface **248** provides the interface between DSL data streams and WAN **260**. DCS Interface **247** provides the interface between DSL data streams and DCS for virtually permanent T or E-carrier connections. By virtually permanent it is meant that a circuit connection is set up by provision instead of user-dial-up. As with PCM Bank **242**, the Access Router **245**, Access Select **244**, DS0 Interface **246**, and DCS interface **247** are unique aspects to the present DSLAM **240** invention.

Given the description above, the general design of the various stages within the new DSLAM circuit **240** required to accomplish the above functions is a routine task well within the abilities of one skilled in the art. The specifics of such implementation are not critical or essential to the present inventions, and will vary from application to application according to system designer requirements.

The novel DSLAM architecture described, combined with DSL connections, can provide the following service needs:

(1) End-to-end dialing via circuit switching. This is attractive for low bit rate DSL access when used with a downstream SAM architecture at CPE **230**, as disclosed in the aforementioned applications noted above, or for time sensitive services such as video conferencing.

(2) End-to-end dialing via packet switching. This data path is most attractive for remote access users do not need real-time services or need very high data (bit) rates.

(3) Access to WAN **260** for high speed, but non-time sensitive services such as Internet access. This type of connection is attractive for users having a network access model, rather than a modem access model at their particular CPE access site.

(4) Virtual permanent connections for corporate users. This feature permits connections by users (usually corporations) whose destination sties can be accessed via T or E class carrier services. The DSLAM architecture described above is a superset of current prior art DSLAM implementation. In other words, the architecture supports all the necessary functions of current prior art DSLAMs, and is therefore backward compatible with existing systems using DSLAMs. Depending on cost constraints, DSLAM **240** can also be implemented without including the features and advantages conferred by some stages such as DCS interface **247** and DS0 interface **246**. Again, this flexibility permits carriers to build systems that are more specifically tailored to their particular cost/functionality targets.

Signaling and Call Setups for End-to-End Connections Using the Present Invention

A description of how the present invention can be used to negotiate rate and establish end-to-end connections for both circuit-switching and packet-switching now follows.

The initial DSLAM access procedures are described first with reference to the flowchart shown in FIG. **4A**.

At step **401**, a remote user at CPE **230** calls a central office site over its DSL, **225**, initiating either a voice connection at **402A**, or a DSL connection at **402B**. If it is a DSL access, a DSL signal (which can be arbitrarily specified) from the remote DSL unit **230** is generated at step **402B**. DSLAM **245** then determines at step **403** whether the call is an analog voice signal or a request for DSL, access by detecting the presence of the specified DSL signal. If it is a DSL call, at step **404** DSLAM **245** routes the DSL data to DSL Bank/Dialing Logic circuit **243**. If it is the DSL signal is not detected, DSLAM **245** instead connects the analog voice signal to PCM bank **242** at step **405**.

After the DSL signal is connected to DSLAM **240**, route selection signaling is sent by the caller at **230** over the DSL carrier and received by DSLAM **240** to direct Access Router **245** at step **406** to select a particular access mode (i.e. PSTN **250**, DCS **270**, or WAN **270**).

The above is merely illustrative of a preferred embodiment of performing the access process between the DSLAM **240** and remote user site **230**. Other suitable variations will be apparent to skilled artisans given the teachings herein. Again, while this embodiment of the present invention is set out in the context of a DSL based application, it will be apparent to those skilled in the art that above description is merely an exemplary implementation. In addition, there may be other types of data path routes connectable through the DSLAM of the present invention which require data handling other than the circuit and/or packet switching capabilities of PSTN **250** and WAN **260**, respectively.

A further description of the various call setup process for each of these modes now follows with reference to the flowcharts at FIGS. 4B–4D.

End to End Snatching Through PSTN 250

With reference to FIG. 4B, assuming the user has opted for a routing through PSTN **250**, the PSTN call setup process **420** can be used to connect an end-to-end circuit via the PSTN **250** and at a rate of multiple of 64 kb/s. Such routing might be requested, for example, where data transfer is time sensitive and requires real time performance circuit-switching connections. It should be appreciated by those skilled in the art that the 64 kb/s figure is merely typical of that used by central offices at this time, and the present invention is not restricted to such specific adaptations.

(1) At step **421**, the user first decides and requests a target data rate X (multiple of 64 kb/s).

(2) The DSL codecs at CPE **231** and DSLAM **245** then decide the available rate Y (Y<=X) at step **422** for DSL **225** by taking into consideration, among other things, the caller requested target rate, line quality of DSL, **225**, etc.

(3) During step **423**, the call request is propagated to the remote CO associated with destination site CPE **231** where at step **424**, DSLAM **240'** of the remote CO then calls the DSL of the called party and performs similar rate negotiation process of the above step **422** to determine an available rate Z on DSL, **225'**.

(4) Depending on the result of step **424**, DSLAM **240** then selects R as the lower of Y and Z at step **425** as the tentative achievable rate for the overall data link.

(5) At step **426**, PSTN **250** then allocates and sets up multiple 64 kb/s connections to try and satisfy the above data rate R. However, the maximum number of switching circuits that the PSTN can set up determines the final actual available rate, R' that can be used in the link.

(6) The PSTN **250** then sends the final rate to both the calling and called parties at step **427**.

(7) After this, at step **428** the end-to-end connection starts to communicate data from user site CPE, **230** to destination site **231** through PSTN **250**.

End to End Switching Through WAN 260

With reference to FIG. 4C, assuming the user has opted for a routing through WAN **260**, the WAN call setup process **430** can be used to connect an end-to-end packet-switching link. Such routing might be requested, for example, where the data transfer is not time sensitive, but requires the current modem-use model.

(1) At step **431**, the user first decides and requests a target data rate X.

(2) The DSL codecs at CPE **231** and DSLAM **245** then decide the available rate Y at step **432** for DSL, **225** by taking into consideration, among other things, the caller requested target rate, line quality of DSL **225**, etc.

(3) During step **433**, the call request is propagated to a CO associated with a destination site CPE **231** where at step **434**, DSLAM **240'** of the remote CO then calls the DSL, of the called party and performs similar rate negotiation process of the above step **432** to determine an available rate Z on DSL, **225'**.

(4) Depending on the result of step **434**, DSLAM **240** then selects R as the lower of data rates Y and Z at step **435** as the tentative achievable rate for the overall data link.

(5) At step **436**, WAN **260** then allocates and sets up the packet connection by trying to meet the above data rate R. However, the maximum number of packets that the WAN can set up determines the final actual available rate, R' that can be used in the link.

(6) WAN **260** then sends the final rate to both the calling and called parties at step **437**.

(7) After this, at step **438**, the end-to-end connection starts to communicate data from user site CPE **230** to destination site **232** through WAN **260**.

End-to-End Path Through An "Always On" Connection

With reference to FIG. 4D, in this case, the DSL connection **225** to the central office is always on. To start the connection (turn it on initially) DSL transceiver at CPE **231** talks to remote DSLAM **240** at the central office at step **441** and negotiates the target rate Y that can be achieved on DSL, **225** based on the loop condition, host processor power at CPE **231**, access cost, and the backbone rate support for WAN **260**.

Once the DSL connection is on, the end-to-en d packet-switching connection is accomplished using process **440** as follows:

(1) The user can set up a Frame Relay or ATM link through WAN **260**. The Frame Relay or ATM network first checks if the rate request Y from the new connection is smaller than the available rate X from the WAN. If not, the requested rate Y is reduced to the available rate X, so that the final Z is the lesser of X and Y.

(2) The requested rate Z is passed over WAN **260** to the destination end **232** at step **442**, which will check at step **443** if the request rate Z can be supported by either another DSL link or a WAN connection. If not, the request is either rejected or the request rate is reduced to a rate R that can be supported. The final actual rate R used to set up the connection is based on the protocol of the selected network.

(3) After this, at step **443** the end-to-end connection starts to communicate data from user site CPE, **230** to destination site **232** through WAN **260**.

Although the present invention has been described in terms of a preferred embodiment, it will be apparent to those skilled in the art that many alterations and modifications may be made to such embodiments without departing from the teachings of the present invention. For example, it is apparent that the present invention would be beneficial used in any xDSL or high speed multi-carrier application environment. Other types of circuits beyond those illustrated in the foregoing detailed description can be used suitably with the present invention. Accordingly, it is intended that the all such alterations and modifications be included within the scope and spirit of the invention as defined by the following claims.

What is claimed is:

1. A method for setting up a data connection between an originating site communications device and a destination site communications device using a public switched network, said method comprising the steps of:

(a) receiving a request for a target data rate X from said originating site; and

(b) determining a maximum available rate Y (Y<=X) available for transmitting data to and/or from said originating site; and

(c) determining a maximum available rate Z for transmitting data to and/or from said destination site;

and

(d) selecting a data rate R, where R is the lesser of {Y, Z} as a tentative achievable rate for the overall data link; and

(e) setting up multiple 64 kb/s connections to effectuate said data connection at the selected data rate R.

2. The method of claim **1**, further including a step (f): notifying both the originating and destination sites after said data connection is set up.

3. The method of claim **2**, further including a step (g): transmitting data between said originating and destination sites at the selected data rate R through said data connection.

4. The method of claim 3, further including a step (h): converting voice signals from the originating site into digital voice signals for routing such signals through a circuit switched network or another data path having minimal data transmission delay characteristics.

5. The method of claim 1, wherein said data includes time sensitive data signals.

6. A method for setting up a data connection between an originating site communications device and a destination site communications device using a packet switching network in a dial-up mode, said method comprising the steps of:

(a) receiving a request for a target data rate X from said originating site; and

(b) determining a maximum available rate Y (Y<=X) available for transmitting data to and/or from said originating site; and

(c) determining a maximum available rate Z for transmitting data to and/or from said destination site; and

(d) selecting a data rate R, where R is the lesser of {Y, Z} as a tentative achievable rate for the data connection; and

(e) setting up packet switching links to effectuate said data connection at the selected data rate R.

7. The method of claim 6, further including a step (f): notifying both the originating and destination sites after said data connection is set up.

8. The method of claim 7, further including a step (g): transmitting data between said originating and destination sites at the selected data rate R through said data connection.

9. The method of claim 8, further including a step (h): converting voice signals from the originating site into digital voice signals for routing such signals through a switched network or another data path having minimal data transmission delay characteristics.

10. The method of claim 6, wherein said data includes non-time sensitive data signals.

11. A method for setting up a data connection between an originating site communications device and a destination site communications device using a digital subscriber loop that is coupled to a central office in an always-on mode, said method comprising the steps of:

(a) initializing the data connection between the originating and destination sites, including determining a maximum data rate X capable of being achieved between said sites; and

(b) receiving a requested data rate Y for transmitting data to and/or from said originating site; and

(c) setting up a packet switched connection for transmitting data to and/or from said originating site;

(d) determining a maximum available rate Z for transmitting data using the packet switched connection, where Z is the lesser of {X, Y} as a tentative achievable rate for the overall data link; and

(e) determining a rate R' which can be supported by data links coupled between said central office and said destination site;

(f) determining a rate R, where R is the lesser of {R', Z} as a tentative achievable rate for the overall data link; and

(g) setting up multiple data packets to effectuate said data connection at the selected data rate R.

12. The method of claim 11, further including a step (h): notifying both the originating and destination sites after said data connection is set up.

13. The method of claim 12, further including a step (i): transmitting data between said originating and destination sites at the selected data rate R through said data connection.

14. The method of claim 13, further including a step (j): converting voice signals from the originating site into digital voice signals for routing such signals through a switched network or another data path having minimal data transmission delay characteristics.

15. The method of claim 14, wherein said data includes non-time sensitive data signals.

16. The method of claim 11, wherein during step (a), the maximum data rate X is determined by evaluating the following parameters: (i) transmitting conditions of said subscriber loop; (ii) processing capabilities at said originating site.

17. The method of claim 16, wherein the rate R' is determined by evaluating the following parameters: (i) transmitting conditions of a subscriber loop coupled to said destination site; and (ii) processing capabilities at said destination site.

18. The method of claim 17, wherein R is selected based on access costs associated with the data connection.

19. The method of claim 18 wherein Z is determined by evaluating a backbone data rate support available for a packet switching network to be used for said data connection.

20. The method of claim 14, wherein time sensitive data signals from the originating site are not routed through the packet switched connection.

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